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May 26, 1995

Defense Technical Information Center
Building 5, Cameron Station
Alexandria, VA 22304-6145

SUBJECT: PERFORMANCE (TECHNICAL) REPORT
ONR Grant Number N00014-93-1-0403

Dear Ladies and Gentlemen,

Per Office of Naval Research Grant Number N00014-93-1-0403 Grant Schedule paragraph 8. (REPORTS AND REPORT DISTRIBUTION:) and Attachment Number 2 (REPORTS AND REPORT DISTRIBUTION), I am providing you two copies of our annual Performance Report for ONR Grant N00014-93-1-0403 entitled ***"Circulation within Monterey Submarine Canyon"*** under the direction of Dr. Leslie Rosenfeld. The Performance Report covers the of period from March 1, 1994 through 28 February 1995.

Please let me know if you have any questions or if I can be of any further assistance to you. You may contact me by (Tel.) 408-647-3776, (FAX) 408-649-8587, or (Email) chlo@mbari.org.

Sincerely,

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IN REPLY REFER TO:

4330
ONR 247
11 Jul 97

From: Director, Office of Naval Research, Seattle Regional Office, 1107 NE 45th St., Suite 350, Seattle, WA 98105

To: Defense Technical Center, Attn: P. Mawby, 8725 John J. Kingman Rd., Suite 0944, Ft. Belvoir, VA 22060-6218

Subj: RETURNED GRANTEE/CONTRACTOR TECHNICAL REPORTS

1. This confirms our conversations of 27 Feb 97 and 11 Jul 97. Enclosed are a number of technical reports which were returned to our agency for lack of clear distribution availability statement. This confirms that all reports are unclassified and are "APPROVED FOR PUBLIC RELEASE" with no restrictions.

2. Please contact me if you require additional information. My e-mail is *silverr@onr.navy.mil* and my phone is (206) 625-3196.

ROBERT J. SILVERMAN

Circulation within Monterey Submarine Canyon

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Goals:

Our long-term research objectives focus on the complex interactions among circulation patterns above, within, and past the mouths of submarine canyons, and with the complex topography associated with them. Our goal is to gain a dynamic understanding of how the circulation patterns within canyons are related to the topographic characteristics of individual canyons, and how features in those patterns can be generalized to fit a variety of similar canyons, so that simplified models of canyon circulation can be developed and evaluated. We would also like to quantify the role of currents within submarine canyons in eroding canyon walls, modifying the sediment patterns on canyon floors, transporting materials between the continental shelf and the deep-sea, and providing food for the large stocks of demersal fish that reside along canyon walls.

Objectives:

Our immediate objective is to analyze one year's worth of data on the water circulation and vertical and lateral transport of suspended particulate matter within Monterey Submarine Canyon. We will use these data to: estimate the transport of water and particulates through the Monterey Submarine Canyon; compare the low frequency circulation and density structure at a "wide" and at a "narrow" portion of the canyon; relate the circulation in the canyon to parameters of the flow over the canyon, deep flow outside the canyon, and to the topographic features of the canyon; evaluate the kinetic energy distribution, including tidal and higher frequencies, as a function of along-canyon distance (and hence canyon width) and depth; investigate the spatial patterns of particulate matter in the water column and examine the relationship between measured currents and volume transport of suspended particulate matter. We will compare our results to published theoretical predictions of circulation within canyons.

Approach:

We are using measurements from a moored array and CTD surveys to address the questions posed above. These moorings supported 6 sediment traps and 12 current meters, 6 of which were modified to measure conductivity and light transmission, in addition to the standard current velocity and temperature. There was also a pressure sensor on each mooring. The array consisted of two cross-canyon sections (Figure 1). Two moorings were deployed in a narrow portion of the canyon, axis depth 1450 m, where the ratio of the internal Rossby radius to the canyon width equals 4. The along-canyon bottom slope in this region is about 3.5 degrees, very close to the expected slope of the characteristics for internal waves of semi-diurnal period. Three moorings are deployed across a wide section of the canyon, axis depth 2837 m, where the ratio of the internal Rossby radius to the canyon width is nearly unity. The bottom slope along the axis at this location is 0.8 degrees, which means that internal waves with period less than about 17 hours can freely propagate up-canyon past this point. The canyon topography for each cross-section, with the instrument locations marked, is depicted in Figure 2.

Flow above the canyon over the narrow section was monitored with a downward-looking acoustic Doppler current profiler on a surface mooring supported by MBARI. At the wide site, there was one current meter above the canyon sill on the central mooring (Figure 2). Near-bottom flow and suspended sediments within the canyon, but 32 km further down-canyon in a water depth of 3223 m, was monitored by a mooring deployed by the USGS. Researchers from the Naval Postgraduate School measured flow over the continental slope south of the canyon.

An analysis of the spatial variability of the energy distribution versus frequency from previously existing current measurements made in and around Monterey Canyon was presented by Rosenfeld et al. (1994). We expect to fold in these older data as we proceed with analyses of the new data set we have just collected.

Tasks Completed:

We deployed 6 subsurface moorings (5 funded by ONR and an additional one funded by USGS) in Monterey Canyon in August 1993, and successfully recovered them all in August 1994. Nearly all instruments on the moorings recorded excellent data. Only the vane of one current meter deployed at the shallowest site in the narrow portion of the canyon (Figure 2) failed. Complete records of temperature, salinity and light transmission were recovered. During the mooring deployment and recovery cruises, as well as on a NMFS cruise in June 1994, multiple CTD casts were made to determine the density and light transmission fields in the vicinity of the moorings. Initial processing of these data have been completed. The CTD survey will be repeated again in November 1994 and box cores will be used to sample sediments in the canyon axis. The canyon topography has already been determined by several previous geological mapping surveys.

Results:

The currents in Monterey Canyon were mainly tidal (Figure 3). At each site, the energy in the tides increased uniformly as you approached the canyon floor. The tidal ellipses were oriented mainly along canyon. Tidal amplitudes in the narrow portion of the canyon were 3 to 4 times larger than were observed in the wider portion. The semimajor axis of the M2 tidal ellipse 100 m above the bed in the narrow axis was 11 cm/s. The mean flow in the narrow portion of the canyon was up-canyon near the canyon rim and down-canyon at the deeper measurement site. There was no strong mean flow in the wider portion of the canyon.

To date, we have analyzed the particulate material collected in the two sediment traps deployed at 780 and 1360 m on the axis mooring in the narrow section of the canyon (Figure 2). The two traps documented dramatically different sediment flux regimes. Extremely large particulate sediment fluxes of 22-60g/m2/day were recorded in the lower trap, located 80 m off the bottom at 1360 m, as compared with mass flux values which ranged from 2-4g/m2/day the upper trap. The 1360 m trap actually overflowed its collection tube after the end of November, with the result that only four 30-day flux events were recorded in the trap sample tube.

Two significantly important events were seen by the bottom instruments at this site. Near the end of the first collection period (8/3-8/31) and into the second month (8/31-9/30), a large amount of black, hydrogen sulfide-rich material formed a very distinctive layer within the sample tube of the bottom trap only. The material most likely originated from the slumping of soft sediments off the adjacent canyon wall. Subsequently, on February 8, a significant event turbidity event that lasted 5 to 7 days was recorded 100 m above the bed (Figure 4). In 4 hours, transmission dropped from values greater than 4 (clear) to values near 0 (blocked). At this same time, a large change was recorded in the pressure record. No significant events were noted in current speed, though the currents were flowing down-canyon. The water associated with the event became slightly warmer and fresher. Unfortunately, the sediment trap at this location had already overflowed, so no sediment was collected in the event.

Impact for Science:

When canyons extend very close to the coast, as in Monterey Bay, they may provide a relatively effective mechanism for transporting sediments, sewage sludge or other materials off the shelf. In addition, submarine canyons off central California are a primary habitat for commercially valuable demersal fish stocks. Yet, for all their significance, the circulation and transport processes in large canyons are not well understood, in part because the complex interactions between topography and circulation are only beginning to be studied. Relatively long-term measurements like we obtained in this program are needed before our community can understand the complicated, time-dependent processes that occur normally in canyons. Long-term measurements are also needed to capture relatively rare events, such as the turbidity event described above.

Relationships to Other Projects:

Rosenfeld and Paduan are co-advising an NPS Ph.D. candidate, Lt. Emil Petruncio, who is studying the internal tide in Monterey Bay. He is using measurements made during NPS student cruises, as well as working on an application of the Princeton Ocean Model. It is expected that the data collected during this ONR-funded experiment will be useful in verifying, and possibly forcing, this numerical model.

Noble and colleagues at the USGS have started a program in Monterey Bay to determine a sediment budget for the region. Because Monterey Canyon may be a primary sink for shelf sediment, this study provides essential information to sediment budget models.

Rosenfeld and Kunze (of UW) have submitted a proposal to NSF to study internal waves in Monterey Submarine Canyon using XBTs and expendable current and dissipation profilers. They have drawn on some of the early results of this experiment, and on Petruncio's work, to design their sampling plan. The use of expendable probes will greatly increase the vertical resolution of the data compared to the moored array and will extend the measurements into the bottom boundary layer.

References:

Rosenfeld, L.K., M.A. Noble, C.H. Pilskaln, F.B. Schwing, 1994: Currents in Monterey Submarine Canyon. EOS, 75, 204.

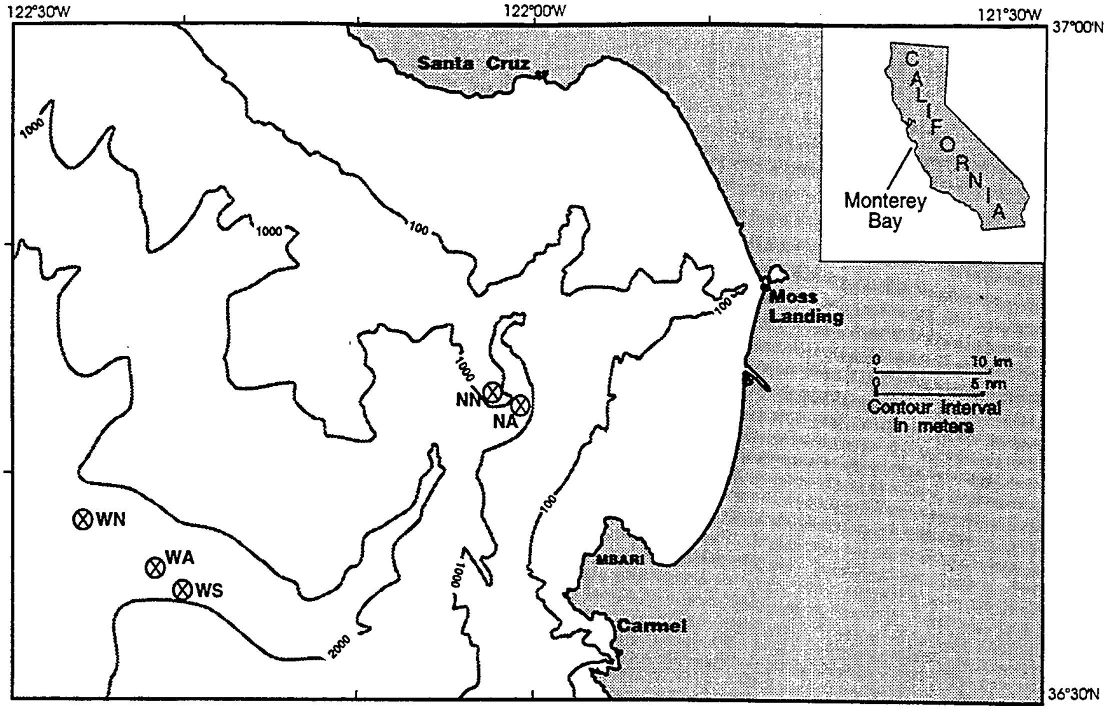

Figure 1. The five mooring sites in Monterey Submarine Canyon are indicated by circled x's.

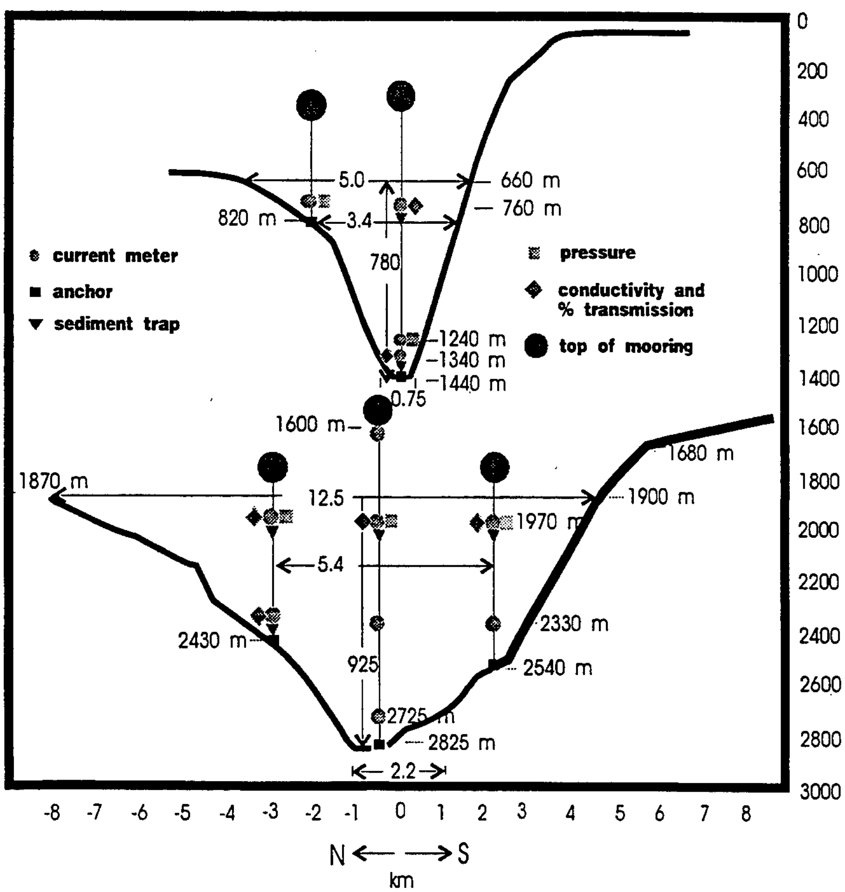

Figure 2. The moorings and instrumentation are shown relative to the topography for the narrow (top) and wide (bottom) canyon sections. Targeted depths are indicated.

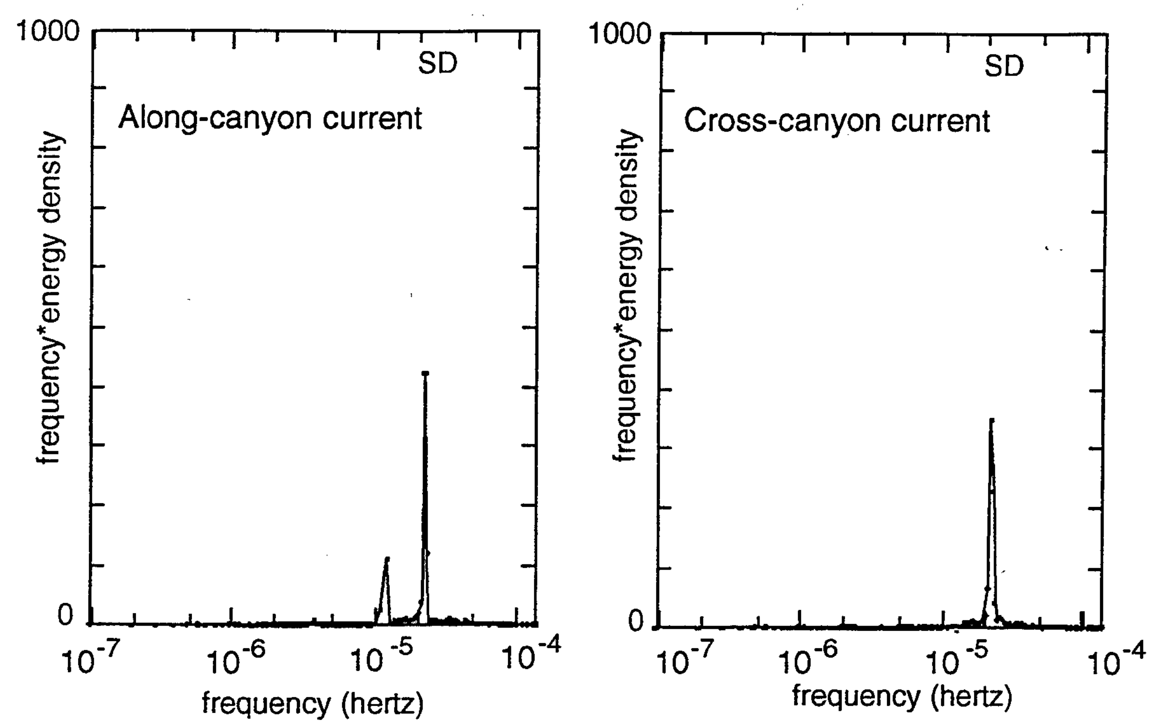

Figure 3. Variance-conserving spectra of currents along the axis at the wide portion of the canyon, water depth 2330 m. SD denotes the semidiurnal tidal frequency

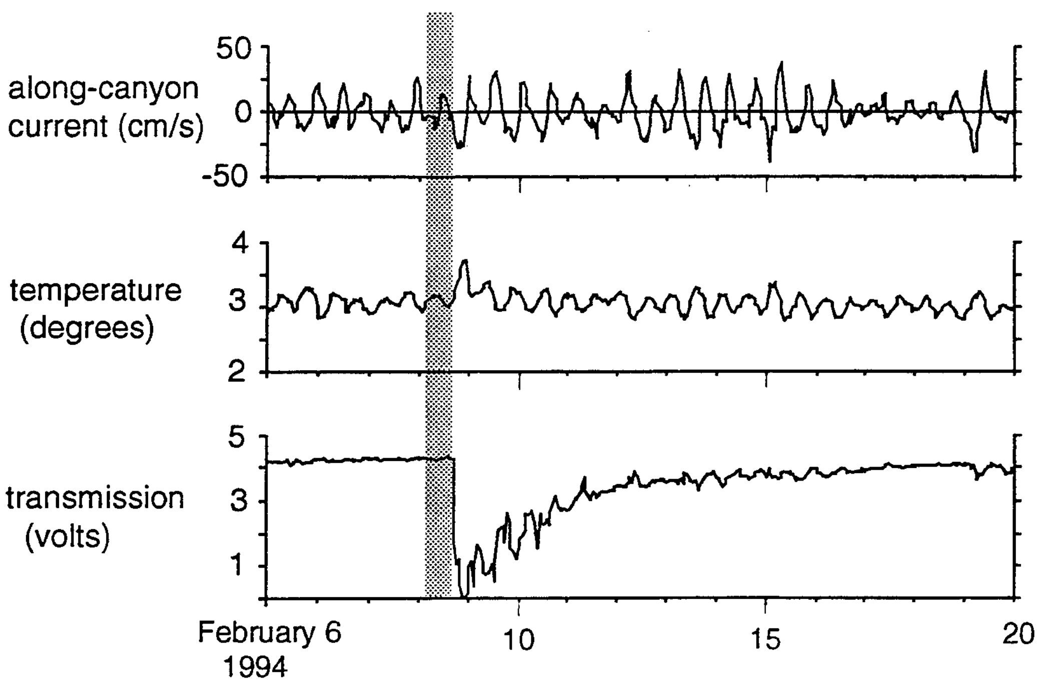

Figure 4. Turbidity event recorded 100 m above the canyon axis in the narrow section of Monterey Canyon.